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Hino et al.

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(54) **TARGET FOR NEUTRON SCATTERING INSTALLATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**^{7} **G21G 1/10**

(52) **U.S. Cl.** **376/194**; 376/192; 376/193; 376/195; 376/196; 376/197; 376/199; 376/202; 376/376; 376/388; 376/398; 376/453; 376/454; 376/102; 376/103; 376/105; 376/106; 376/108; 376/109; 250/250; 250/305; 250/315.3; 250/396; 250/492.23

(58) **Field of Search** 376/192, 193, 376/194, 195, 196, 197, 199, 202, 376, 388, 398, 453, 454, 102, 103, 105, 106, 108, 109; 250/250, 305, 315.3, 396, 492.23

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(57) **ABSTRACT**

Flow of mercury from a liquid-heavy-metal inflow port toward an inner forward end of a container body is rectified by a plurality of incoming-passage guide vanes in a liquid-heavy-metal incoming passage. Flow of the mercury from the forward end of the container body toward a liquid-heavy-metal outflow port is rectified by a plurality of return-passage guide vanes in a liquid-heavy-metal return passage. As a result, occurrence of stagnation and/or recirculation flows of the mercury in the container body is suppressed and a steady and highly uniform stream of the mercury is formed throughout in the container body. The container body is covered with a container outer shell to prevent any leakage of the mercury to outside due to a damage of the container body.

3 Claims, 6 Drawing Sheets

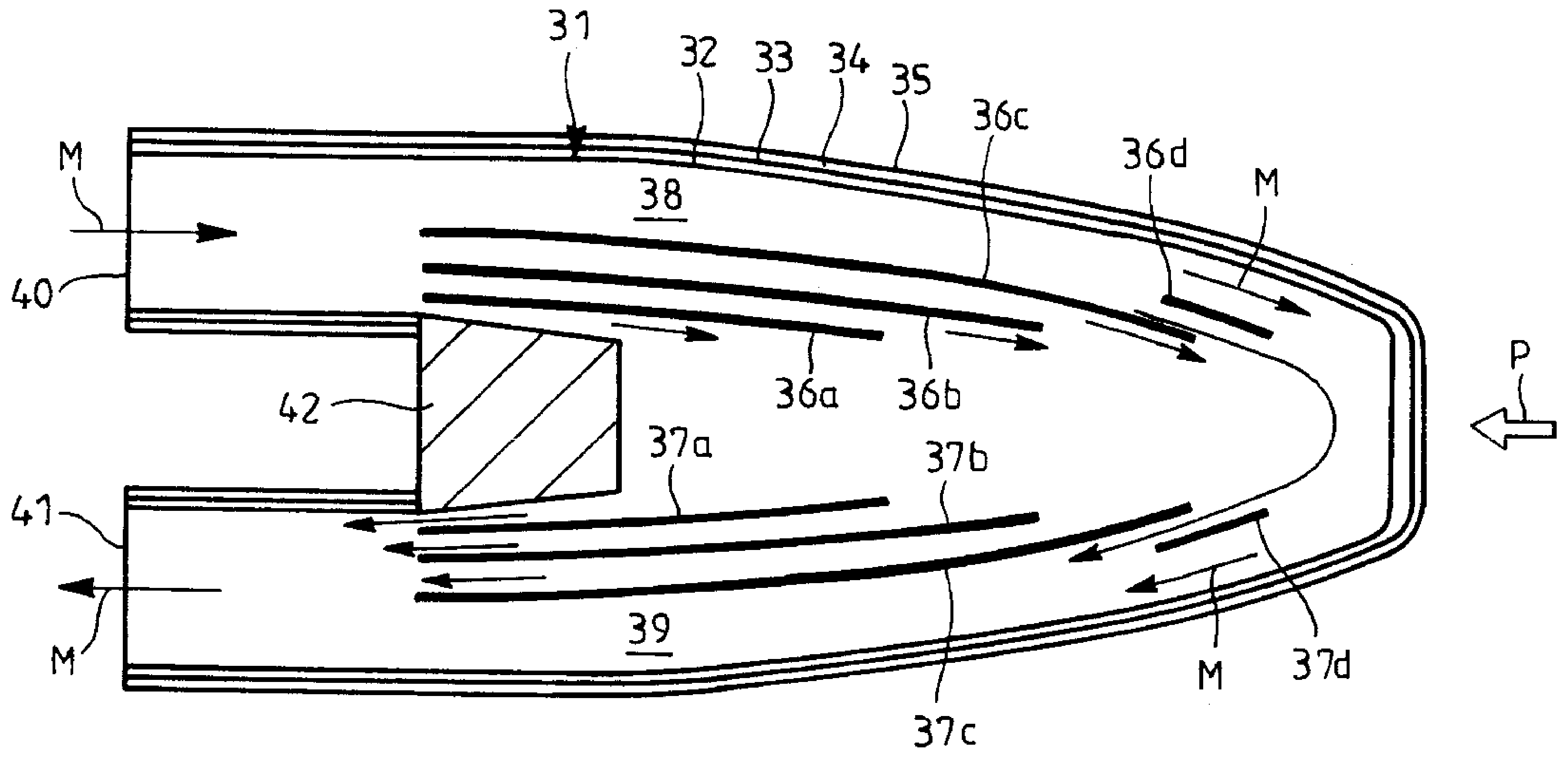


FIG. 1

PRIOR ART

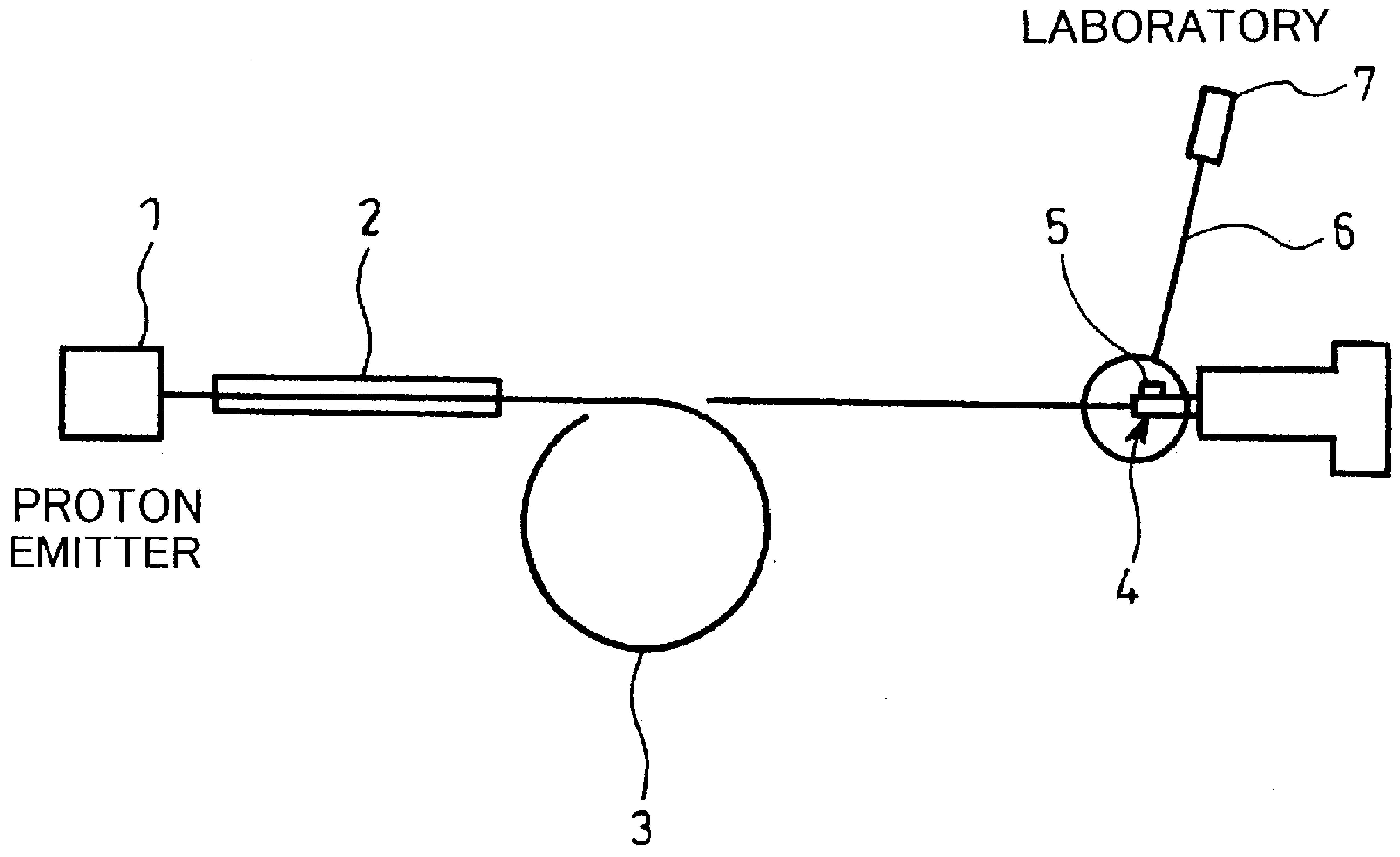
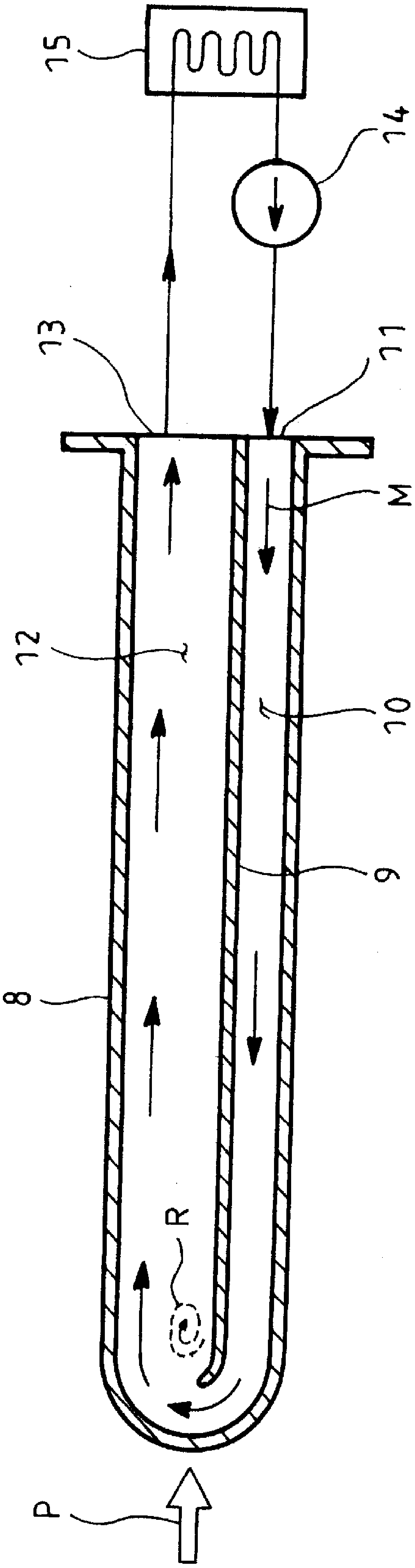


FIG. 2

PRIOR ART



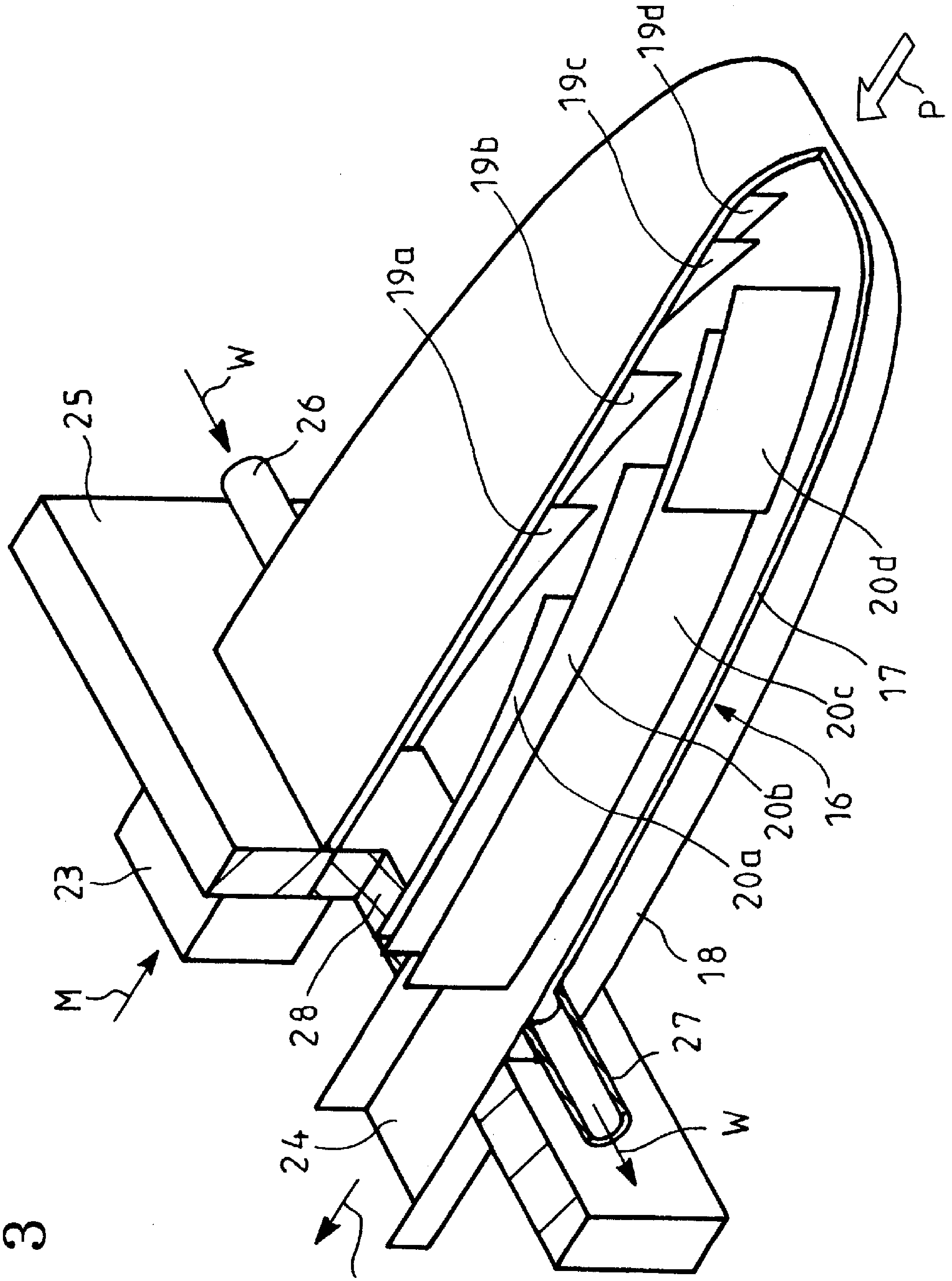


FIG. 3

FIG. 4

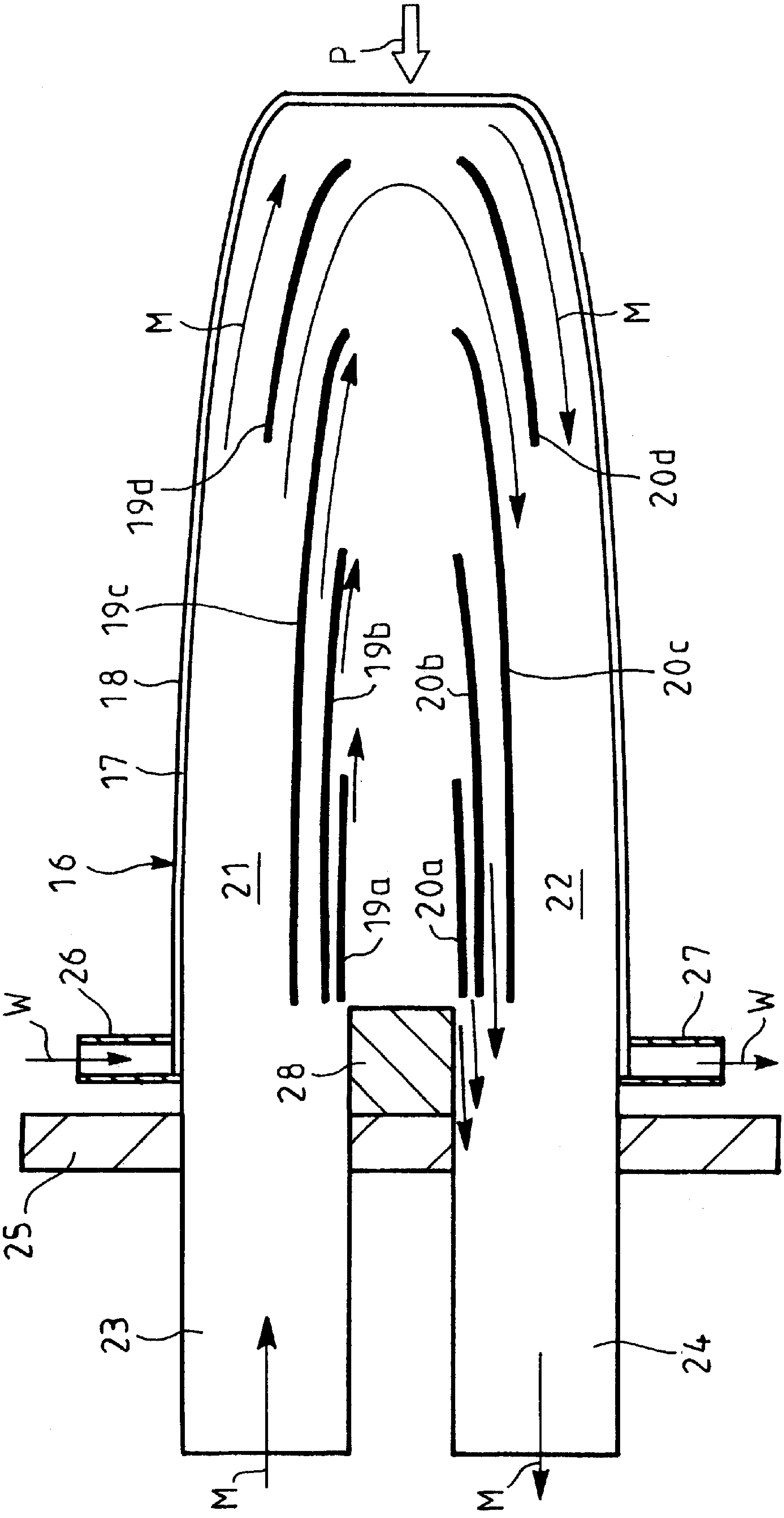

P
M
M
19d
20d
19c
18
17
16
21
19b
20b
20c
22
19a
20a
W
26
27
W
28
25
23
24
M
M

FIG. 5

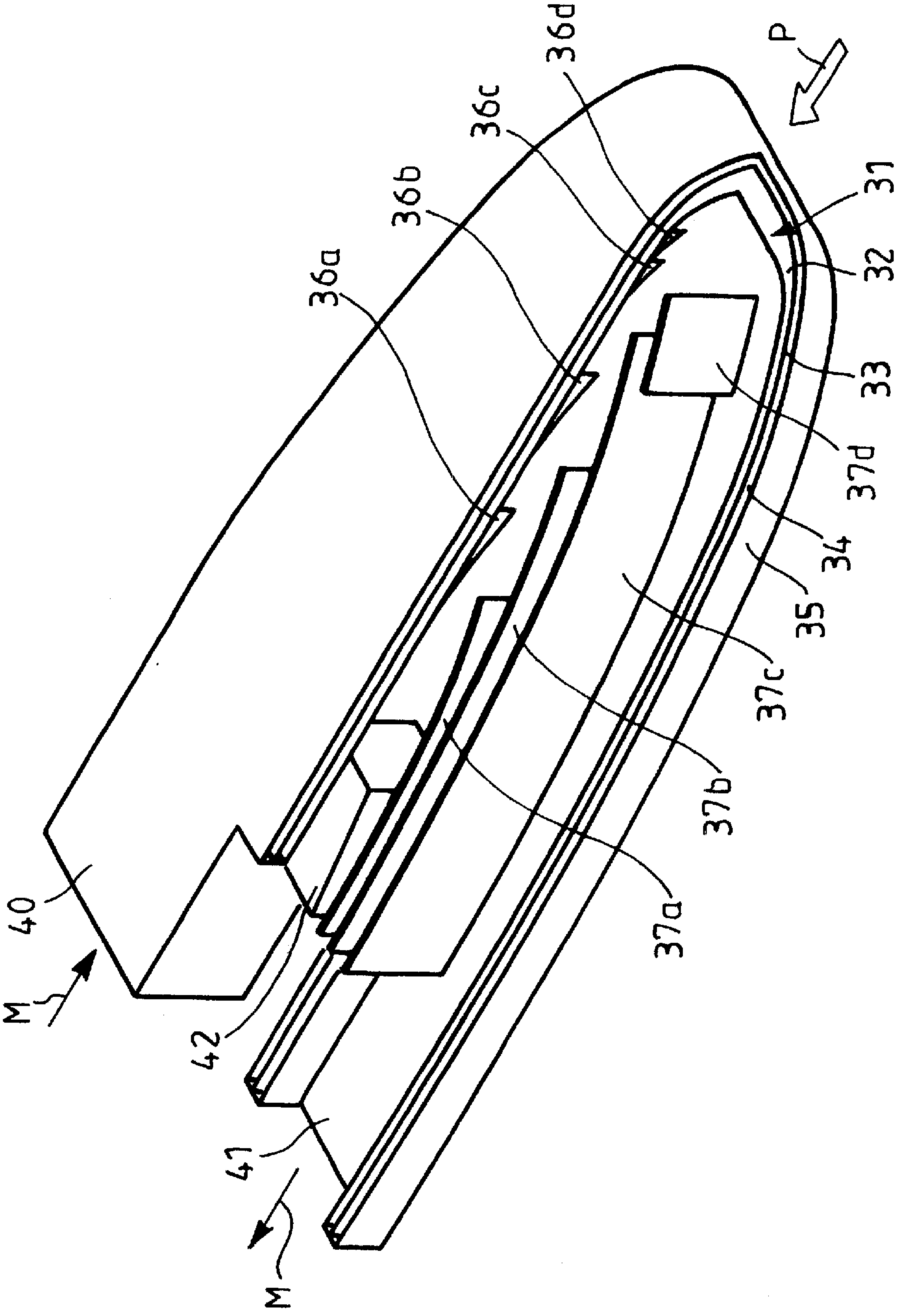
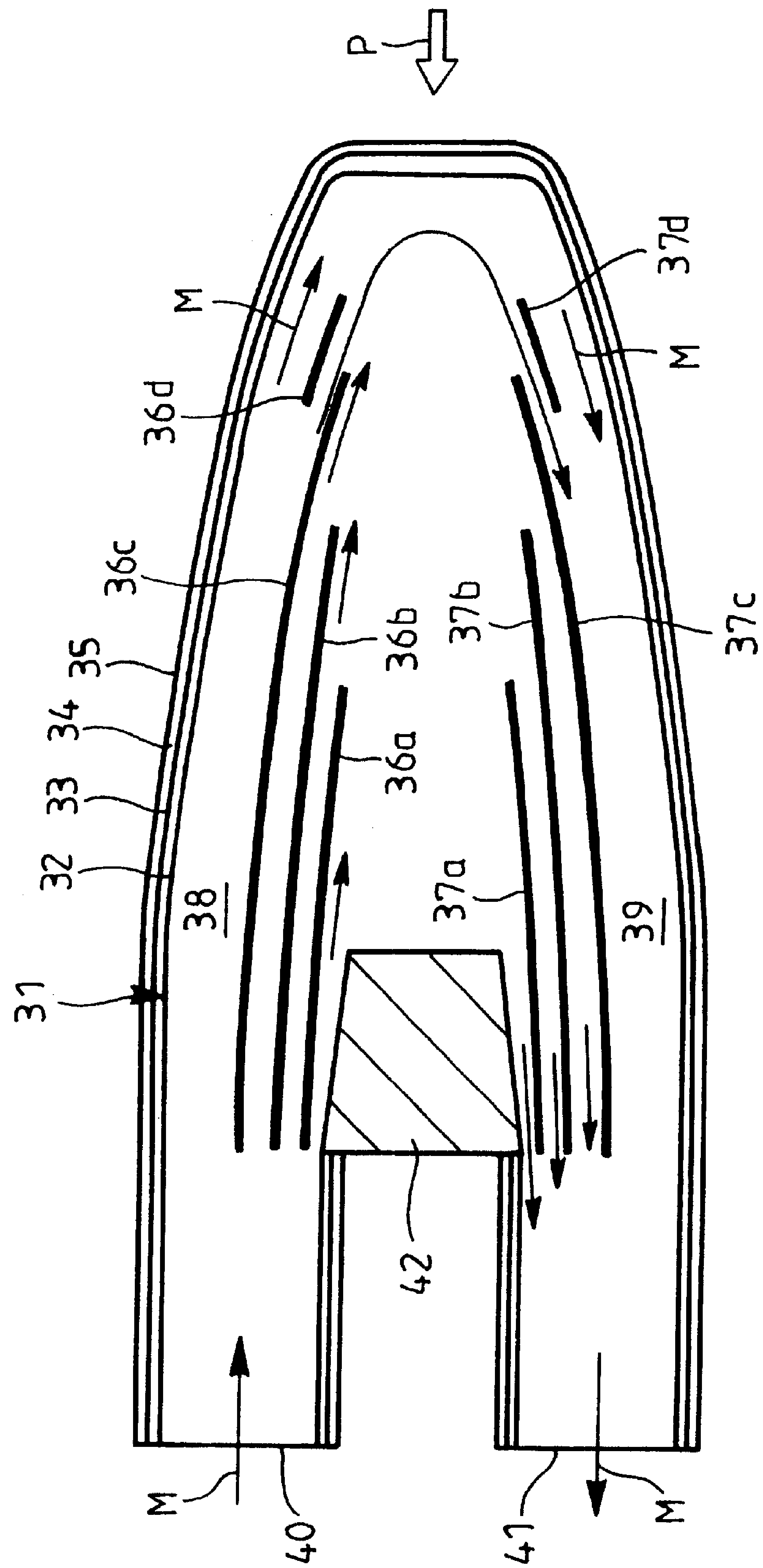


FIG. 6



TARGET FOR NEUTRON SCATTERING INSTALLATION

BACKGROUND OF THE INVENTION

The present invention relates to a target for a neutron scattering installation.

FIG. **1** shows an example of a neutron scattering installation for performing various research studies on physical properties using neutrons. In the installation, protons from a proton emitter **1** are accelerated by a linear accelerator **2** to enter into an accumulation ring **3** where the protons are circulated by curving their orbits with a deflecting electromagnet and are increased in velocity using high frequency electric current until required energy can be reached.

The protons thus having the required energy are emitted from the ring **3** to a target **4** where they are brought to collide against liquid heavy metal such as mercury held in the target **4**. Fast neutrons generated by nuclear spallation reaction are passed through a moderator such as liquid hydrogen (20 K; 1.5 MPa) held in a moderator container **5** so that they are converted into thermal or cold neutrons suitable for research purpose; these are guided via a beam line **6** to a laboratory **7**.

FIG. **2** shows a conventional target for a neutron scattering installation which comprises a container body **8** arranged to counter a proton beam P, which advances approximately horizontally, and a partition **9** having its opposite edges contiguous with a lower inner surface portion of the body **8** and extending from a base end of the body **8** to a position near a forward end of the body **8**.

The container body **8** has, at its base end, inflow and outflow ports **11** and **13**. The inflow port **11** serves to communicate outside of the body **8** with a liquid-heavy-metal incoming passage **10**, which is a space defined between the inner surface of the body **8** and a lower surface of the partition **9**. The outflow port **13** serves to communicate outside of the body **8** with a liquid-heavy-metal return passage **12**, which is a space defined between the inner surface of the body **8** and an upper surface of the partition **9**.

The inflow port **11** is connected with a discharge port of a pump **14** and the outflow port **13** is connected with a suction port of the pump **14** via a heat exchanger **15**. Thus, the pump **14**, inflow port **11**, incoming and return passages **10** and **12**, outflow port **13** and heat exchanger **15** compose a closed loop which is filled with mercury M as liquid heavy metal.

In the target shown in FIG. **2**, fast neutrons are generated by collision of the protons against the mercury M, which flows via the incoming passage **10** to an inner forward end of the container body **8**. The mercury M having received heat from the nuclear spallation reaction is then guided via the return passage **12** to the heat exchanger **15** so as to be cooled down.

However, in the system shown in FIG. **2**, the whole of the mercury M supplied to the inflow port **11** makes up a mercury stream which flows via the incoming passage **10** to the inner forward end of the body **8** and turns back via the return passage **12**, so that stagnation and/or re-circulation flows R tend to occur near the inner forward end of the body **8**. Constant stagnation of the mercury M may lead to occurrence of local increase in temperature (hot spots).

Since the mercury M is brought to continuously flow at higher flow rate in the container body **8** so as to remove the heat caused by nuclear spallation, extremely high burdens are applied on cooling means of, for example, the mercury circulation pump **14** and heat exchanger **15**, which makes it difficult to cope with nuclear spallation reaction having higher heat generated.

The present invention was made to solve the above problems and has its object to provide a target for a neutron scattering installation which can provide a stead and highly uniform stream of liquid heavy metal throughout in the system.

BRIEF SUMMARY OF THE INVENTION

In a target for a neutron scattering installation according to any of claims **1** to **3** of the invention, the flow of the liquid heavy metal from the liquid-heavy-metal inflow port toward the inner forward end of the container body is rectified by a plurality of incoming-passage guide vanes installed closer to one side in the container body, and the flow of the liquid heavy metal from the forward end of the container body toward the liquid-heavy-metal outflow port is rectified by a plurality of return-passage guide vanes installed closer to the other side in the container body, thereby suppressing occurrence of stagnation and/or re-circulation flows of the liquid heavy metal in the container body.

In a target for a neutron scattering installation according to claim **2** of the invention, the container body in which the liquid heavy metal flows is covered with a container outer shell, thereby preventing any leakage of the liquid heavy metal to outside as may be caused by damage of the container body.

In a target for a neutron scattering installation according to claim **3** of the invention, the container body in which the liquid heavy metal flows is dually covered by container intermediate and outer shells, thereby preventing any leakage of the liquid heavy metal to outside as may be caused by damage of the container body.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically shows an example of a neutron scattering installation;

FIG. **2** schematically shows a conventional target for a neutron scattering installation;

FIG. **3** is a perspective view partly in section of a first embodiment according to the invention;

FIG. **4** is a horizontal sectional view of the first embodiment;

FIG. **5** is a perspective view partly in section of a second embodiment of the invention; and

FIG. **6** is a horizontal sectional view of the second embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will be described in conjunction with the attached drawings.

FIGS. **3** and **4** represent a first embodiment of a target for a neutron scattering installation according to the invention which comprises a thin-wall container body **16** arranged such that a proton beam P advancing approximately horizontally can enter a forward end of the body **16**, a thin-wall container outer shell **18** for covering the container body **16** such that a space **17** is defined between the outer shell **18** and an outer surface of the body **16** and incoming- and return-passage guide vanes **19***a*–**19***d* and **20***a*–**20***d* installed in the container body **16**. A space in the container body **16** closer to one side of the body **16** provides a liquid-heavy-metal incoming passage **21** and a space in the container body **16** closer to the other side of the body **16** provides a liquid-heavy-metal return passage **22**.

The container body **16** has, at its base ends, a liquid-heavy-metal inflow port **23** for inflow of the mercury M from outside to the incoming passage **21** and a liquid-heavy-metal outflow port **24** for outflow of the mercury M from the return passage **22** to outside, independently from each other. A flange **25** is mounted to surround these ports **23** and **24**.

The outer shell **18** is liquid-tightly mounted at its base ends to the flange **25**.

A portion of the outer shell **18** closer to one base end thereof is provided with a cooling-medium inflow port **26** for inflow of cooling water W to the space **17** from outside. A portion of the outer shell **18** closer to the other base end thereof is provided with a cooling-medium outflow port **27** for outflow of the cooling water W to outside from the space **17**.

In the space **17**, a guide member (not shown) contiguous with the inner surface of the outer shell **18** and with the outer surface of the container body **16** is installed at an appropriate position, which will contribute to prevention of short-circuit flow of the cooling water W from the inflow port **26** to the outflow port **27**.

The incoming-passage guide vanes **19***a*–**19***d* are arranged in the incoming passage **21** and have upper and lower edges contiguous with the inner surface of the container body **16**. The guide vanes **19***a*–**19***d* are laterally spaced apart from each other and are gradually curved toward the center of the container body **16** in a direction from the base end to the forward end of the container body **16**.

The return-passage guide vanes **20***a*–**20***d* are arranged in the return passage **22** and have upper and lower edges contiguous with the inner surface of the container body **16**. The guide vanes **20***a*–**20***d* are laterally spaced apart from each other and are gradually curved toward the center of the container body **16** in a direction from the base end to the forward end of the container body **16**.

These guide vanes **19***a*–**19***d* and **20***a*–**20***d* also serve as reinforcement members for the container body **16**.

The container body **16** is provided, at a center of its base end, with a beam stopper **28** for blocking protons which pass through the outer shell **18** and container body **16** and advance between the guide vanes **19***a*–**19***d* and **20***a*–**20***d*.

When neutrons are to be generated in the target shown in FIGS. **3** and **4**, the cooling water W is continuously supplied from outside of the container body **16** to the inflow port **26**, passes through the space **17** and is continuously discharged through the outflow port **27** to outside of the container body **16**.

The mercury M is continuously supplied from outside of the container body **16** to the inflow port **23**, passes through the incoming and return passages **21** and **22** and is continuously discharged through the outflow port **24** to outside of the container body **16**.

Under such conditions, proton beam P is irradiated so that protons pass through the outer shell **18** and container body **16** and collide against the mercury M which is flowing through the incoming and return passages **21** and **22**. As a result, neutrons are generated.

In the target for the neutron scattering installation as described above, the flow of the mercury M through the incoming passage **21** toward the inner forward end of the container body **16** is rectified by a plurality of incoming-passage guide vanes **19***a*–**19***d* and the flow of the mercury M through the return passage **22** toward the outflow port **24** is rectified by a plurality of return-passage guide vanes **20***a*–**20***d*. As a result, occurrence of stagnation and/or re-circulation flows of the mercury M at the inner forward end of the container body **16** is suppressed. Consequently, a stead and highly uniform stream of the mercury M is formed throughout in the container body **16**.

Therefore, increase in temperature due to stagnation of the mercury M is avoided and erosion due to re-circulation, too fast flow or the like does not occur on the inner surface of the container body **16**.

Flow rate of the mercury M may be adjusted by varying the distance ratio between the guide vanes **19***a*–**19***d* and/or **20***a*–**20***d*.

Further, heat generated by nuclear spallation reaction can be removed by mercury and the cooling water W passing through the space **17**, which will relieve thermal load on the container body **16**, outer shell **18** and mercury M and alleviate the burden on cooling means of, for example, a pump **14** for circulating the mercury M and a heat exchanger **15** (FIG. **2**). Thus, nuclear spallation reaction having higher heat generated can be coped with.

Furthermore, since the thermal load is relieved as described above and the guide vanes **19***a*–**19***d* and **20***a*–**20***d* are used as reinforcement members for the container body **16**, the container body **16** and outer shell **18** can be designed with thin wall, which will contribute to improvement of the efficiency to generate neutrons.

In addition, the container body **16** in which the mercury M flows is covered with the outer shell **18**, which will prevent any leakage of the mercury M to outside as may occur when the container body **16** is damaged.

FIGS. **5** and **6** represent a second embodiment of a target for a neutron scattering installation of the present invention which comprises a thin-wall container body **31** arranged such that a proton beam P advancing approximately horizontally can enter a forward end of the body **31**, a thin-wall container intermediate shell **33** for covering the container body **31** such that a space **32** is defined between the intermediate shell and an outer surface of the container body **31**, a thin-wall container outer shell **35** for covering the intermediate shell **33** such that a space **34** is defined between the outer shell **35** and an outer surface of the intermediate shell **33** and incoming- and return-passage guide vanes **36***a*–**36***d* and **37***a*–**37***d* installed in the container body **31**. A space in the container body **31** closer to one side of the body **31** provides a liquid-heavy-metal incoming passage **38** and a space in the container body **31** closer to the other side of the body **31** provides a liquid-heavy-metal return passage **39**.

The container body **31** has, at its base ends, a liquid-heavy-metal inflow port **40** for inflow of the mercury M from, outside to the incoming passage **38** and a liquid-heavy-metal outflow port **41** for outflow of the mercury M from the return passage **39** to outside, independently from each other.

The container body **31** and intermediate shell **33** are closely fitted at,their base ends to each other to close a base end portion of the space **32** which is filled with helium (He) gas.

The intermediate and outer shells **33** and **35** are closely fitted at their base ends to each other to close a base end portion of the space **34**. Through a cooling-medium feed passage (not shown), heavy water is supplied from outside of the container body **31** to the space **34** and is discharged to outside of the container body **31** via a cooling-medium discharge passage (not shown).

In the space **34**, a guide member (not shown) contiguous with the inner surface of the outer shell **35** and outer surface of the intermediate shell **33** is installed at appropriate position, which will contribute to prevention of short-circuit flow of the heavy water from the cooling-medium feed passage to the cooling-medium discharge passage.

The incoming-passage guide vanes **36***a*–**36***d* are arranged in the incoming passage **38** and have upper and lower edges contiguous with the inner surface of the container body **31**. The guide vanes **36***a*–**36***d* are laterally spaced apart from each other and are gradually curved toward the center of the container body **31** in a direction from the base end toward the forward end of the container body **31**.

The return-passage guide vanes **37***a*–**37***d* are arranged in the return passage **39** and have upper and lower edges contiguous with the inner surface of the container body **31**. The guide vanes **37***a*–**37***d* are laterally spaced apart from each other and are gradually curved toward the center of the container body **31** in a direction from the base end to the forward end of the container body **31**.

These guide vanes **36***a*–**36***d* and **37***a*–**37***d* also serve as reinforcement members for the container body **31**.

The container body **31** is provided, at a center of its base end, with a beam stopper **42** for blocking protons, which pass through the outer shell **35**, intermediate shell **33**, and container body **31** and advance between the guide vanes **36***a*–**36***d* and **37***a*–**37***d*.

When neutrons are to be generated in the target shown in FIGS. **5** and **6**, the heavy water is continuously supplied from outside of the container body **31** to the feed passage, passes through the space **34** and is continuously discharged through the discharge passage to outside of the container body **31**.

The mercury M is continuously supplied from outside of the container body **31** to the inflow port **40**, passes through the incoming and return passages and **38 39** and is continuously discharged through the outflow port **41** to outside of the container body **31**.

Under such conditions, proton beam P is irradiated so that protons pass through the outer shell **35**, intermediate shell **33** and container body **31** and collide against the mercury M which is flowing through the incoming and return passage **38** and **39**. As a result, neutrons are generated.

In the target for neutron scattering installation as described above, the flow of the mercury M through the incoming passage **38** toward the inner forward end of the container body **31** is rectified by a plurality of the incoming-passage guide vanes **36***a*–**36***d* and the flow on the mercury M through the return passage **39** toward the outflow port **41** is rectified by a plurality of return-passage guide vanes **37***a*–**37***d*. As a result, occurrence of stagnation and/or re-circulation flows of the mercury M at the inner forward end of the container body **31** is suppressed. Consequently, highly uniform and steadily flowing stream of the mercury M is formed throughout in the container body **31**.

Therefore, increase in temperature due to stagnation of the mercury M is avoided and erosion due to recirculation, too fast flow or the like does not occur on the inner surface of the container body **31**.

Flow rate of the mercury M may be adjusted by varying the distance ratio between the guide vanes **36***a*–**36***d* and/or **37***a*–**37***d*.

Further, heat generated by nuclear spallation reaction can be removed by mercury and the heavy water passing through the space **34**, which will relieve thermal load on the container body **31**, intermediate shell **33**, outer shell **35** and mercury M and alleviate the burden on cooling means of, for example, a pump **14** for circulating the mercury M and a heat exchanger **15** (FIG. **4**). Thus, nuclear spallation reaction having high heat generated can be coped with.

Furthermore, since the thermal load is relieved as described above and the guide vanes **36***a*–**36***d* and **37***a*–**37***d* are used as reinforcement members for the container body **31**, the container body **31** and intermediate shell **33** can be designed with thin wall, which will contribute to improvement of the efficiency to generate neutrons.

In addition, the container body **31** in which the mercury M flows is dually covered by the intermediate and outer shells **33** and **35**, which will prevent any leakage of the mercury M to outside as may occur when the container body **31** is damaged.

The space **32** may be filled with fluid other than helium. Fluid other than heavy water may be passed through the space **34**.

What is claimed is:

1. A target for a neutron scattering installation comprising:

a container body configured such that a proton beam advancing approximately horizontally to a base of the container body enters a forward end of the container body and the proton beam divides the container body in two halves;

a plurality of incoming-passage guide vanes with upper and lower edges contiguous with an inner surface portion of the container body, said plurality of incoming-passage guide vanes being disposed in a first half of the container body, laterally spaced apart from each other with a gradual enlargement of a radius of each incoming-passage guide vane, and curved toward a center of the container body in a direction from an end of the base toward the forward end of the container body;

a plurality of return-passage guide vanes with upper and lower edges contiguous with the inner surface portion of the container body, said plurality of return-passage guide vanes being disposed in a second half of the container body, laterally spaced apart from each other with a gradual enlargement of a radius of each return-passage guide vane, and curved toward the center of the container body in the direction from the base end to the forward end of the container body;

a liquid-heavy-metal inflow port configured to allow an inflow of liquid heavy metal from outside of the container body to the incoming-passage guide vanes in the container body; and

a liquid-heavy-metal outflow port configured to allow an outflow of the liquid heavy metal from the return-passage guide vanes outside the container body.

2. A target according to claim **1**, further comprising a container outer shell configured to cover the container body.

3. A target according to claim **1**, further comprising:

a container intermediate shell configured to cover the container body; and

a container outer shell configured to cover the intermediate shell.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,477,217 B1
DATED : November 5, 2002
INVENTOR(S) : Hino et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Item [73], Assignee, should read:

-- [73] Assignees: **Japan Atomic Energy Research Institute**,
Tokyo-to (JP); **Ishikawajima-Harima**
Jukogyo Kabushiki Kaisha, Tokyo-to (JP) --

Signed and Sealed this

First Day of June, 2004

Jon W. Dudas

JON W. DUDAS
Acting Director of the United States Patent and Trademark Office